HNU-ITP-96-1

Top-squark mixing effects in the supersymmetric electroweak corrections to top quark production at the Tevatron

Jin Min Yang[a,b] and Chong Sheng Li[a,c]

[a]CCAST(World Laboratory)

P.O.Box 8730, Beijing 100080, P. R. China

[b] Physics Department, Henan Normal University,

Xinxiang, Henan 453002, P.R.China [1]

[c] Physics Department, PeKing University

Beijing 100871, P. R. China

ABSTRACT

Taking into account the mixing effects between left- and right-handed top-squarks, we calculate the genuine supersymmetric eletroweak correction to top quark production at the Tevatron in the minimal supersymmetric model. The analytic expressions of the corrections to both the parton level cross section and the total hadronic cross section are presented. Some numerical examples are also given to show the size of the corrections.

PACS number: 14.80Dq; 12.38Bx; 14.80.Gt

[1]mailing address

1. Introduction

The top quark has been discovered by CDF and D0 collaborations at the Tevatron [1]. The mass and production cross section are found to be $176 \pm 8(stat) \pm 10(syst) \left(199^{+19}_{-21}(stat) \pm 22(syst)\right)$ GeV and $6.8^{+3.6}_{-2.4}\,(6.4 \pm 2.2)\,Pb$ by CDF (DO) collaboration. The comparison of the theoretical calculation of the top quark production cross section with experimental results is necessary in the test of the mechanism by which top quarks are produced. Within the framework of the Standard Model (SM) the next-to-leading-order calculation for the QCD processes was completed several years ago[2]. Recent works [3] have extended those results with the inclusion of the exact order α_s^3 corrected cross section and the resummation of the leading soft gluon corrections in all orders of perturbation theory. The cross section was predicted to be $\sigma_{t\bar{t}}(m_t = 176GeV) = 4.79^{+0.67}_{-0.41}Pb$[3]. The latest results given by Berger [4] was $\sigma_{t\bar{t}}(m_t = 175GeV) = 5.52^{+0.07}_{-0.45}Pb$. The one-loop electroweak corrections to the cross section were found to be only a few percent[5]. Therefore, the results of theoretical prediction in the SM are almost consistent with the experimental results within the region of the errors.

Since the corrections to top quark production cross section above 20% are potentially observable at the Tevatron, it is tempting to calculate the radiative corrections arising from the new physics beyond the SM. In the minimal supersymmetric model (MSSM), the Yukawa correction and supersymmetric QCD correction were calculated in Refs.[6,7]. These corrections cannot reach the observable level for experimentaly allowed parameter values. The genuine supersymmetric electroweak corrections of order $\alpha m_t^2/m_W^2$, which arise from loops of chargino, neutralino and squark, have also been calculated by us in Ref.[8] and its erratum [9], where we neglected the mixings between left- and right-handed squarks and assumed the mass degeneracy for all squarks. In such a simple case, the analytic results were quite simple and the numerical size of the corrections could not reach the observable level for squark mass heavier than 100 GeV. However, due to the possible significant mixing effects between left- and right-handed top-squarks, which is suggested by low-energy supergravity models but is completely general [10], the mass splitting between the two mass eigenstates

of top squark may be quite large. The supersymmetric electroweak corrections may be sensitive to top-squark mixing effects.

In this paper, taking into account the mixing effects between left- and right-handed top-squarks, we present the genuine supersymmetric eletroweak correction to top quark production at the Tevatron in the minimal supersymmetric model. In Sec.2, we briefly overview top-squark mixing. In Sec.3, we give the analytic expressions of the corrections to both the parton level cross section and the total hadronic cross section. In Sec.4 we present some numerical examples to show the size of the corrections.

2. Top-squark mixing

The mass matrix of top-squarks takes the form [10]

$$\begin{aligned}
-L_m &= (\tilde{t}_L^* \ \tilde{t}_R^*)\begin{pmatrix} m^2_{\tilde{t}_L} & m_t M_{LR} \\ m_t M_{LR} & m^2_{\tilde{t}_R}\end{pmatrix}\begin{pmatrix}\tilde{t}_L \\ \tilde{t}_R\end{pmatrix} \\
m^2_{\tilde{t}_L} &= M^2_{\tilde{t}_L} + m_t^2 + \cos(2\beta)(\frac{1}{2} - \frac{2}{3}\sin^2\theta_W)M_Z^2 \\
m^2_{\tilde{t}_R} &= M^2_{\tilde{t}_R} + m_t^2 + \frac{2}{3}\cos(2\beta)\sin^2\theta_W M_Z^2 \\
M_{LR} &= \mu\cot\beta + A_t\tilde{M} \qquad (1)
\end{aligned}$$

where $M^2_{\tilde{t}_L}, M^2_{\tilde{t}_R}$ are the soft SUSY-breaking mass terms for left- and right-handed top-squarks,μ is the coefficient of the H_1H_2 mixing term in the superpotential, $A_t\tilde{M}$ is the coefficient of the dimension-three trilinear soft SUSY-breaking term $\tilde{t}_L\tilde{t}_R H_2$, and $\tan\beta = v_2/v_1$ is the ratio of the vacuum expectation values of the two Higgs doublets.

The mass eigenstates of top-squark are obtained by

$$\begin{pmatrix}\tilde{t}_1 \\ \tilde{t}_2\end{pmatrix} = R\begin{pmatrix}\tilde{t}_L \\ \tilde{t}_R\end{pmatrix} = \begin{pmatrix}\cos\theta & \sin\theta \\ -\sin\theta & \cos\theta\end{pmatrix}\begin{pmatrix}\tilde{t}_L \\ \tilde{t}_R\end{pmatrix} \qquad (2)$$

and the masses of $\tilde{t}_{1,2}$ are given by

$$R \ \ M^2_{\tilde{t}} \ \ R^T = \begin{pmatrix} m^2_{\tilde{t}_1} & 0 \\ 0 & m^2_{\tilde{t}_2}\end{pmatrix} \qquad (3)$$

The expressions of θ and $m^2_{\tilde{t}_{1,2}}$ are given by

$$\tan 2\theta = \frac{2M_{LR}m_t}{m^2_{\tilde{t}_L} - m^2_{\tilde{t}_R}} \qquad (4)$$

$$m^2_{\tilde{t}_{1,2}} = \frac{1}{2}\left[m^2_{\tilde{t}_L} + m^2_{\tilde{t}_R} \mp \sqrt{(m^2_{\tilde{t}_L} - m^2_{\tilde{t}_R})^2 + 4M^2_{LR}m_t^2}\right] \qquad (5)$$

For sbottoms, since we neglect the mixing between left- and right-handed sbottoms, we have

$$m^2_{\tilde{b}_{1,2}} = m^2_{\tilde{b}_{L,R}} = m_b^2 + M^2_{\tilde{b}_{L,R}} \pm \cos(2\beta)(T^3_{L,R} - Q_b \sin^2\theta_W) M_Z^2 \tag{6}$$

where $T^3_{L,R} = -\frac{1}{2}, 0$ and $Q_b = -\frac{1}{3}$. $M_{\tilde{b}_{L,R}}$ are the soft SUSY-breaking mass terms for left- and right-handed sbottoms.

3. Analytical expression of the correction

At the Tevatron, the top quark is dominantly produced via quark-antiquark annihilation [11]. The genuine supersymmetric electroweak correction of order $\alpha m_t^2/m_W^2$ to the amplitude is contained in the correction to the vertex of top-quark color current. The relavent Feynman diagrams are shown in Fig.1 in Ref.[7]. The Feynman rules can be found in Ref.[12]. In our calculation, we use dimensional regularization to regulate all the ultraviolet divergences in the virtual loop corrections and we adopt the on-mass-shell renormalization scheme[13]. The renormalized amplitude for $q\bar{q} \to t\bar{t}$ can be written as

$$M_{ren} = M_0 + \delta M, \tag{7}$$

where M_0 is the amplitude at tree-level and δM is the correction to the amplitude, which are given by

$$\begin{aligned} M_0 &= \bar{v}(p_2)(-ig_s T^A \gamma^\nu) u(p_1)\ \frac{-ig_{\mu\nu}}{\hat{s}}\ \bar{u}(p_3)(-ig_s T^A \gamma^\mu) v(p_4), & (8)\\ \delta M &= \bar{v}(p_2)(-ig_s T^A \gamma^\nu) u(p_1)\ \frac{-ig_{\mu\nu}}{\hat{s}}\ \bar{u}(p_3)\delta\Lambda^\mu v(p_4). & (9)\end{aligned}$$

Here, p_1, p_2 denote the momenta of the incoming partons, and p_3, p_4 are used for outgoing t quark and its antiparticle. $\hat{s}$ is center-of-mass energy of parton level process. $\delta\Lambda^\mu$ stand for the genuine supersymmetric electroweak correction to the vertex of top-quark color current, which are given by

$$\begin{aligned} \delta\Lambda^\mu &= -ig_s T^A \frac{g^2 m_t^2}{32\pi^2 m_W^2 \sin^2\beta}\left[\gamma^\mu F_1 + \gamma^\mu\gamma_5 F_2\right. \\ &\quad \left. + k^\mu F_3 + k^\mu \gamma_5 F_4 + ik_\nu \sigma^{\mu\nu} F_5 + ik_\nu\sigma^{\mu\nu}\gamma_5 F_6\right], \end{aligned} \tag{10}$$

where $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$ and the form factor F_i are obtained by

$$F_i = F_i^c + F_i^n, \tag{11}$$

where F_i^c and F_i^n arise from chargino and neutralino digrams, respectively. F_i^c are given as

$$\begin{aligned}
F_1^c &= \sum_{j=1,2} V_{j2}V_{j2}^* \left[c_{24} + m_t^2(c_{11}+c_{21}) + (\frac{1}{2}B_1 + m_t^2 B_1')(m_t, \tilde{M}_j, m_{\tilde{b}})\right] && (12)\\
F_2^c &= \sum_{j=1,2} V_{j2}V_{j2}^* \left[c_{24} + \frac{1}{2}B_1(m_t, \tilde{M}_j, m_{\tilde{b}})\right], && (13)\\
F_3^c &= \frac{1}{2}m_t \sum_{j=1,2} V_{j2}V_{j2}^* \left(c_{21} - 2c_{23}\right), && (14)\\
F_4^c &= \frac{1}{2}m_t \sum_{j=1,2} V_{j2}V_{j2}^* \left(c_{21} + 4c_{22} - 4c_{23}\right), && (15)\\
F_5^c &= -\frac{1}{2}m_t \sum_{j=1,2} V_{j2}V_{j2}^* \left(c_{11} + c_{21}\right), && (16)\\
F_6^c &= -\frac{1}{2}m_t \sum_{j=1,2} V_{j2}V_{j2}^* \left(c_{11} + c_{21} - 2c_{12} - 2c_{23}\right), && (17)\\
& && (18)
\end{aligned}$$

where the functions $c_{ij}(-p_3, p_3+p_4, \tilde{M}_j, m_{\tilde{b}}, m_{\tilde{b}})$ and B_1 are the 3-point and 2-point Feynman integrals [14]. The chargino masses $\tilde{M}_j$ and matrix elements V_{ij} depend on parameters $M, \mu, \tan\beta$, whose expressions can be found in Ref.[12]. $B'_{0,1}$ are defined by

$$B'_{0,1}(m, m_1, m_2) = \frac{\partial B_{0,1}(p, m_1, m_2)}{\partial p^2}|_{p^2=m^2}, \tag{19}$$

F_i^n are obtained by

$$\begin{aligned}
F_i^n &= F_i^{\tilde{t}_1} + F_i^{\tilde{t}_2} + F_i^s \quad (\text{for i} = 1, 2) && (20)\\
F_i^n &= F_i^{\tilde{t}_1} + F_i^{\tilde{t}_2} \quad (\text{for i} = 3, 4, 5, 6) && (21)
\end{aligned}$$

F_1^s and F_2^s are given by

$$\begin{aligned}
F_1^s = \sum_{j=1}^{4} \Big\{ & \frac{1}{2}N_{j4}N_{j4}^* \left[B_1(m_t, \tilde{M}_{0j}, m_{\tilde{t}_1}) + B_1(m_t, \tilde{M}_{0j}, m_{\tilde{t}_2})\right] \\
& + m_t^2 N_{j4}N_{j4}^* \left[B_1'(m_t, \tilde{M}_{0j}, m_{\tilde{t}_1}) + B_1'(m_t, \tilde{M}_{0j}, m_{\tilde{t}_2})\right] \\
& + m_t \tilde{M}_{0j} N_{j4}N_{j4} \sin(2\theta) \left[B_0'(m_t, \tilde{M}_{0j}, m_{\tilde{t}_2}) - B_0'(m_t, \tilde{M}_{0j}, m_{\tilde{t}_1})\right] \Big\} \qquad (22)
\end{aligned}$$

$$F_2^s = \sum_{j=1}^{4} \frac{1}{2} N_{j4} N_{j4}^* \cos(2\theta) \left[B_1(m_t, \tilde{M}_{0j}, m_{\tilde{t}_1}) - B_1(m_t, \tilde{M}_{0j}, m_{\tilde{t}_2}) \right] \quad (23)$$

$F_i^{\tilde{t}_1}$ are given by

$$\begin{aligned}
F_1^{\tilde{t}_1} &= \sum_{j=1}^{4} \left\{ N_{j4} N_{j4}^* \left[c_{24} + m_t^2 (c_{11} + c_{21}) \right] - \sin(2\theta) N_{j4} N_{j4} m_t \tilde{M}_{0j} (c_0 + c_{11}) \right\} && (24) \\
F_2^{\tilde{t}_1} &= \sum_{j=1}^{4} N_{j4} N_{j4}^* c_{24} \cos(2\theta) && (25) \\
F_3^{\tilde{t}_1} &= \sum_{j=1}^{4} \left[\frac{1}{2} m_t N_{j4} N_{j4}^* (c_{21} - 2c_{23}) + \frac{1}{2} \sin(2\theta) N_{j4} N_{j4} \tilde{M}_{0j} (2c_{12} - c_{11}) \right] && (26) \\
F_4^{\tilde{t}_1} &= \frac{1}{2} \cos(2\theta) m_t \sum_{j=1}^{4} N_{j4} N_{j4}^* (c_{21} + 4c_{22} - 4c_{23}) && (27) \\
F_5^{\tilde{t}_1} &= \sum_{j=1}^{4} \left[-\frac{1}{2} m_t N_{j4} N_{j4}^* (c_{11} + c_{21}) + \frac{1}{2} \sin(2\theta) N_{j4} N_{j4} \tilde{M}_{0j} (c_0 + c_{11}) \right] && (28) \\
F_6^{\tilde{t}_1} &= -\frac{1}{2} \cos(2\theta) m_t \sum_{j=1}^{4} N_{j4} N_{j4}^* (c_{11} - 2c_{12} + c_{21} - 2c_{23}) && (29)
\end{aligned}$$

where $c_{ij}(-p_3, p_3 + p_4, \tilde{M}_{0j}, m_{\tilde{t}_1}, m_{\tilde{t}_1})$ are the 3-point Feynman integrals[14]. The neutralino masses $\tilde{M}_{0j}$ and matrix elements N_{ij} are obtained by diagolis the matrix Y [12]. Giving the values for the parameters $M, M', \mu, \tan\beta$, the matrix N and N_D can be obtained numerically. Here, the parameters M, M' are the masses of gauginos corresponding to $SU(2)$ and $U(1)$, respectively. With the grand unification assumption, i.e. $SU(2) \times U(1)$ is embedded in a grand unified theory, we have the relation $M' = \frac{5}{3} \frac{g'^2}{g^2} M$. $F_i^{\tilde{t}_2}$ are given by

$$F_i^{\tilde{t}_2} = F_i^{\tilde{t}_1} \Big|_{\sin(2\theta) \to -\sin(2\theta), \cos(2\theta) \to -\cos(2\theta), m_{\tilde{t}_1} \to m_{\tilde{t}_2}} \quad (30)$$

The renormalized cross-section for parton level process $q\bar{q} \to t\bar{t}$ are given by

$$\hat{\sigma}(\hat{s}) = \hat{\sigma}^0 + \Delta\hat{\sigma}, \quad (31)$$

with

$$\begin{aligned}
\hat{\sigma}^0 &= \frac{8\pi\alpha_s^2}{27\hat{s}^2} \beta_t (\hat{s} + 2m_t^2), && (32) \\
\Delta\hat{\sigma} &= \frac{8\pi\alpha_s^2}{9\hat{s}^3} \beta_t \frac{g^2 m_t^2}{32\pi^2 m_W^2 \sin^2\beta} \left[\frac{2}{3} F_1 \hat{s} (\hat{s} + 2m_t^2) + 2F_5 m_t \hat{s}^2 \right], && (33)
\end{aligned}$$

where $\beta_t = \sqrt{1 - 4m_t^2/\hat{s}}$.

The hadronic cross section is obtained by convoluting the subprocess cross section $\hat{\sigma}_{ij}$ of partons i, j with parton distribution functions $f_i^A(x_1, Q), f_j^B(x_2, Q)$, which is given by

$$\sigma(S) = \sum_{i,j} \int_{\tau_0}^{1} \frac{d\tau}{\tau} \left(\frac{1}{S} \frac{dL_{ij}}{d\tau} \right) (\hat{s}\hat{\sigma}_{ij}), \tag{34}$$

with

$$\frac{dL_{ij}}{d\tau} = \int_{\tau}^{1} \frac{dx_1}{x_1} \left[f_i^A(x_1, Q) f_j^B(\tau/x_1, Q) + (A \leftrightarrow B) \right] \tag{35}$$

In the above the sum runs over all incoming partons carrying a fraction of the proton and antiproton momenta ($p_{1,2} = x_{1,2}P_{1,2}$), $\sqrt{S} = 1.8$ TeV is the center-of-mass energy of Tevatron, $\tau = x_1 x_2$ and $\tau_0 = 4m_t^2/S$. As in Ref.[3], we do not distinguish the factorisation scale Q and the renormalisation scale μ and take both as the top quark mass. In order to compare our results with the Yukawa corrections in Ref.[6], we use the same parton distribution function as in ref.[6], i.e. the Morfin-Tung leading-order parton distribution function [15].

4. Numerical examples and discussion

In the numerical examples presented in Figs.1-3, we fixed $M = 200GeV, \mu = -100GeV$ and used the relation $M' = \frac{5}{3}\frac{g'^2}{g^2}M$ to fix M'. Also we assumed $M_{\tilde{t}_R} = M_{\tilde{t}_L} = M_{\tilde{b}_L}$ which depend on sbottom mass $m_{\tilde{b}} \equiv m_{\tilde{b}_1}$ as in Eq.(6). For $\tan\beta$ and the mixing parameter M_{LR}, we restrict them to the range $\tan\beta \leq 0.25$[6], $M_{LR} \leq 3m_{\tilde{b}_1}$[16]. Other input parameters are $m_Z = 91.188GeV$, $\alpha_{em} = 1/128.8$, and $G_F = 1.166372 \times 10^{-5}(GeV)^{-2}$. m_W is determined through [17]

$$m_W^2 (1 - \frac{m_W^2}{M_Z^2}) = \frac{\pi\alpha}{\sqrt{2}G_F} \frac{1}{1 - \Delta r}, \tag{36}$$

where, to order $O(\alpha m_t^2/m_W^2)$, Δr is given by [18]

$$\Delta r \sim -\frac{\alpha N_C c_W^2 m_t^2}{16\pi^2 s_W^4 m_W^2}. \tag{37}$$

The relative correction to the hadronic cross section as a function of sbottom mass is presented in Fig.1 for $\tan\beta = 0.25$ and $\tan\beta = 1$, respectively. Since the

correction is proportional to $1/\sin^2\beta$, the size of correction for $\tan\beta = 0.25$ is much larger than the corresponding size for $\tan\beta = 1$. In the range $m_{\tilde{b}} < 150$ GeV, the correction is very sensitive to sbottom mass. The correction can be either negative or positive, depending on sbottom mass. For $m_{\tilde{b}} > 200$ GeV, the correction drops to about zero size, showing the decoupling behaviour of MSSM. Each plot in Fig.1 has a sharp dip, which occurs at the threshold point $m_t = m_{\tilde{b}} + \tilde{M}_j$. The chargino masses $\tilde{M}_{1,2} = (230, 100) GeV$ for $\tan\beta = 0.25$ and $\tilde{M}_{1,2} = (220, 120) GeV$ for $\tan\beta = 1$, thus the threshold point locates at $m_{\tilde{b}} = 76$ GeV for $\tan\beta = 0.25$ and $m_{\tilde{b}} = 56$ GeV for $\tan\beta = 1$.

Fig.2 show the dependence of the relative correction to the hadronic cross section on the value of $\tan\beta$ for sbottom mass $m_{\tilde{b}} = 100$ GeV and 150 GeV, respectively. The correction is very sensitive to $\tan\beta$ in the range $\tan\beta < 1$. When $\tan\beta << 1$, the correction size gets very large since it is proportional to $1/\sin^2\beta$.

Fig.3 is the plot of the relative correction to the hadronic cross section versus the top-squark mixing parameter M_{LR}. The corresponding neutralino masses in this figure are (122, 115, 77, 229) GeV and chargino masses are $(230, 100)$ GeV. The starting point $M_{LR} = 0$ correspondes to no-mixing case, at which top-squark masses $m_{\tilde{t}_{1,2}} = m_{\tilde{t}_{L,R}} = (213, 216)$ GeV and the mixing angel $\theta = 0$. As M_{LR} increases, the mass splitting between two top-squarks increases. At $M_{LR} = 200$ GeV, top-squark masses $m_{\tilde{t}_{1,2}} = (103, 285)$ GeV and the mixing angel $\theta = 0.775$. The two sharp dips in the plot correspond to two threshold points at about $M_{LR} = 200$ GeV and 230 GeV, at which $m_t = m_{\tilde{t}_1} + \tilde{M}_{0j}$.

So, from Figs.1-3 we found that only for $\tan\beta < 1$ and $m_{\tilde{b}} < 150$ GeV the correction size may exceed 20%. For $\tan\beta \geq 1$ or $m_{\tilde{b}} > 150$ the correction size can only reach a few percent. In Ref.[6], the Yukawa correction from the SUSY Higgs sector to the hadronic cross section was found to be very small for $\tan\beta = 1$, on the order of a percent, and only for minimum value $\tan\beta = 0.25$ the correction can be above 10% but never exceed 20%. Therefore, the genuine supersymmetric electroweak corrections are comparable to the Yukawa correction from the SUSY Higgs sector.

In conclusion, we presented the anlytical expression for the genuine supersym-

metric electroweak corrections of order $\alpha m_t^2/m_W^2$ to top quark pair production at the Tevatron with the consideration of top-squark mixing. Numerical examples showed that only for $\tan\beta < 1$ and $m_{\tilde{b}} < 150$ GeV the correction can exceed 20%. In the most favorable case, these supersymmetric corrections, combined with Yukawa corrections of the Higgs sector and also SUSY QCD correction, are potentially observable at Tevatron and could be used to place restrictions on MSSM.

ACKNOWLEDGMENTS

We thank Jorge L. Lopez, Raghavan Rangarajan and Jaewan Kim for comparing their numerical results of neutralino masses and Feynman integrals $B_{0,1}, c_0, c_{ij}$ with ours.

This work was supported in part by the Foundation for Outstanding Young Scholars of Henan Province.

References

[1] CDF Collaboration, Phys.Rev.Lett. **74**, 2626(1995);
D0 Collaboration, Phys.Rev.Lett. **74**, 2632(1995).

[2] P.Nason, S.Dawson and R.K.Ellis, Nucl.Phys. **B303**, 609 (1988);
G.Altarelli et al., Nucl.Phys. **B308**, 724 (1988);
W.Beenaker et al., Phys.Rev.D **40**, 54 (1989).

[3] E.Laenen, J.Smith and W.L.van Neerven, Phys.Lett. **B321**,254 (1994).

[4] E.L.Berger and H.Contopanagos, Argonne ANL-HEP-PR-95-31.

[5] W. Beenakker et al., Nucl.Phys. **B411**, 343 (1994).

[6] A Stange and S.Willenbrock, Phys.Rev. D**48**, 2054 (1993).

[7] C.S.Li, B.Q.Hu, J.M.Yang and C.G.Hu, Phys.Rev. D**52**, 5014(1995).

[8] J.M.Yang and C.S.Li, Phys.Rev. D**52**, 1541 (1995).

[9] J.M.Yang and C.S.Li, Erratum of Ref.[8], to appear in Phys.Rev. D.

[10] J.Ellis and S.Rudaz, Phys.Lett.**B128**, 248 (1983)
A.Bouquet, J.Kaplan and C.Savoy, Nucl.Phys.**B262**, 299 (1985).

[11] F.Berends, J.Tausk and W.Giele, Phys.Rev.D**47**, 2746(1993).

[12] H. E. Haber and C. L. Kane, Phys. Rep. **117**, 75 (1985);
J. F. Gunion and H. E. Haber, Nucl. Phys. **B272**, 1 (1986).

[13] K.I.Aoki et al., Prog.Theor.Phys.Suppl. **73**, 1 (1982);
M.Bohm, W.Hollik, H.Spiesbergerm, Fortschr. Phys. **34**, 687 (1986).

[14] A. Axelrod, Nucl. Phys. **B209**, 349 (1982);
G. Passarino and M. Veltman, Nucl. Phys. **B160**, 151 (1979);

[15] J.Morfin and W.K.Tung, Z.Phys. **C52**, 13 (1991).

[16] D.Garcia, R.A.Jimenez, J.Sola and W.Hollik, Nucl. Phys. **B427**, 53 (1994).

[17] A. Sirlin, Phys. Rev. D**22**, 971 (1980);
W. J. Marciano and A. Sirlin, Phys. Rev. D**22**, 2695 (1980); (E) D**31**, 213 (1985);
A. Sirlin and W. J. Marciano, Nucl. Phys. **B189**, 442 (1981);
M. Böhm, W. Hollik and H. Spiesberger, Fortschr. Phys. **34**, 687 (1986).

[18] W. J. Marciano and Z. Parsa, Annu. Rev. Nucl. Sci.**36**, 171 (1986);
W. Hollik, Report No. CERN 5661-90 (1990) (unpublished).

Figure Captions

Fig.1 The plot of relative correction to the hadronic cross section versus sbottom mass, where $M_{LR} = 1.5m_{\tilde{b}}$.

Fig.2 The plot of relative correction to the hadronic cross section versus $\tan\beta$, where $M_{LR} = 1.5m_{\tilde{b}}$.

Fig.3 The plot of the relative correction to the hadronic cross section versus the top-squark mixing parameter M_{LR}.